Doel 3 & Tihange 2 Reactor Pressure Vessel Flaw Indications



60

F. Van Wonterghem J. Bens

Federal Agency for Nuclear Control Belgium

2013-03-13 Doel 3 & Tihange 2 RPV Issue

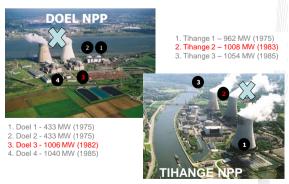


Overview

- 1. Introduction & Safety Concern
- 2. Safety assessment process: actors, timing
- 3. Manufacturing of RPV
- 4. In-service inspections
- 5. Metallurgical origin and evolution of indications
- 6. Material properties
- 7. Structural integrity of RPV
- 8. FANC Conclusions Current Status

2013-03-13 Doel 3 & Tihange 2 RPV Issue





2013-03-13 Doel 3 & Tihange 2 RPV Issu



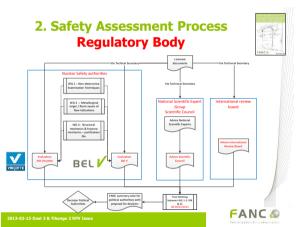
1. Introduction & Safety Concern

- Flaw Indications found during 2012 RPV In-service inspections at Doel 3 & Tihange 2
- Safety concern: Is structural integrity of the reactor pressure vessel still maintained at all times and in all circumstances?



FANC 🚳

2013-03-13 Doel 3 & Tihange 2 RPV Issue



2. Safety Assessment Process Timing

- June-July 2012: Flaw Indications found at Doel 3 RPV
- September 2012: Flaw Indications found at Tihange 2 RPV
- 05/12/2012: Electrabel Safety Cases
- End of December: Evaluation reports of Bel V, AIB Vincotte, International Review Board & Scientific Council → input for FANC
- 30/01/2013: Publication of FANC Provisional Evaluation Report: additional analysis and tests are necessary
- 04/02/2013: Licensee action plan to fulfill FANC requirements (approved by FANC on 06/02/2013)



FANC

2013-03-13 Doel 3 & Tihange 2 RPV Issue

3. Manufacturing of reactor pressure vessels **Characteristics & Regulatory Framework**

Unit	Grid Connection	RPV manufactured by
Doel 1&2	02/1975 12/1975	Forges du Creusot/Cockerill
Doel 3 / Tihange 2	10/1982 02/1983	Krupp/RDM (1974-75)
Doel 4 / Tihange 3	07/1985 07/1985	Japan Steel Works
Tihange 1	10/1975	Creusot-Loire

Construction requirements

- American rules and reglementations
 ASME III + Complementary requirements
 Transposition of ASME regulatory aspects to Belgian context



3. Manufacturing of reactor pressure vessels



FANC CONCLUSIONS

- Manufacturing files were retrieved and examined
- Manufacturing inspections performed as required
- Hydrogen flakes should have been reported at initial inspection, but RPV were considered "acceptable" according to ASME III
- Are ASME III criteria adequate?



4. In Service Inspection **Number of indications** # 600 # 600 1 # 600 1 00 00 19800 # 600 0

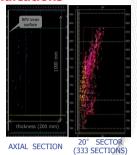
W.EL.			Doel 3	Tihange 2
48.00x3	The same	RVH flange *	3	5
1.87	author and	RPV flange	2	19
		Nozzle shell	11	0
	780	Upper core shell	857	1 931
100 100 100 100 100 100 100 100 100 100	Lil Years A	Lower core shell	7 205	80
		Transition ring	71	0
		Total	8 149	2 035
1	4	* m	anual examination	FANCE

3

4. In Service Inspection RPV flaw indications

- Typical RPV wall cross-section in the affected volume
- The central strip of core shells is affected
- Flaw indications appear nearly-laminar and form a cluster sinking from the clad interface to a maximum depth of 120mm.

Source: Flectrabel



FANC

....

4. In service inspections

- FANC CONCLUSIONS
- Actual presence of flaw indications is confirmed
- Validation using AREVA block known to contain hydrogen flakes ongoing
- Some uncertainty still exists regarding the capability of the ISI techniques to properly detect and characterize all present flaws

FANC REQUIREMENTS

- The licensee shall demonstrate that the applied ultrasonic testing procedure allows the detection of the higher tilt defects with a high level of confidence.
- The licensee shall include a set of defects partially hidden by other defects for macrographic examination, to confirm whether the sizing method continues to function well.
- Full qualification program (long-term)

2013-03-13 Doel 3 & Tihange 2 RPV Issu



5. Metallurgical origin and evolution of the indications

FANC CONCLUSIONS

- Hydrogen flakes is most likely origin: number, size, location in zone of macro-segregation, orientation
- Exact root causes difficult to identify
- Significant evolution of hydrogen flakes during reactor operation unlikely

FANC REQUIREMENTS

- The licensee shall perform follow-up in-service inspections during the next planned outage for refuelling to ensure that no evolution of the flaw indications has occurred during operation.
 - LICENSEE ACTION: Identical in-service inspection during next outage + report on comparison with special attention to potential detected evolution

2013-03-13 Doel 3 & Tihange 2 RPV Issu



6. Material propertie

FANC CONCLUSIONS

- Some uncertainty on representativeness of material testing program
- More experimental data on tensile and toughness properties of the materials are needed to validate the approach followed in the structural integrity assessment.

FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall complete material testing program using samples with macro-segregations containing hydrogen flakes: small-scale specimen tests (local toughness tests at hydrogen flake crack tip, local tensile tests on ligament material near the flakes) + large scale tests (see § 9)
- The licensee shall perform additional measurements of the current residual hydrogen content in specimens with hydrogen flakes

2013-03-13 Doel 3 & Tihange 2 RPV Issue



7. Structural integrity assessment

FANC CONCLUSIONS

- Deterministic flaw evaluation of each indication performed (modelling of flaws, grouping criteria,...)
- Screening criterion showed that very large majority of indications has no safety impact
- ASME III primary stress limits satisfied
- · Fatigue crack growth is very small

FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall evaluate the impact of the possible non-reporting of flaws with higher tilts on the results of the structural integrity assessment
 - LICENSEE ACTION: If needed, additional sensitivity study for higher tilt flaw

2013-03-13 Doel 3 & Tihange 2 RPV Issue



7. Structural integrity assessment



FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall complete the on-going material testing program by testing larger specimens containing hydrogen flakes, with the following 2 objectives:
 - Objective 1: Tensile tests on samples with (inclined) multiple hydrogen flake defects, which shall in particular demonstrate that the material has sufficient ductility and load bearing capacity, and that there is no premature brittle fracture.
 - LICENSEE ACTION: On-going test program at SCK.CEN: Large tensile specimens containing flakes parallel and with 20° tilt angle to axis (2 tests at room temperature, 2 tests at -80° C)

2013-03-13 Doel 3 & Tihange 2 RPV Issue



7. Structural integrity assessment

FANC REQUIREMENTS (Prerequisite to restart of units)

- The licensee shall complete the on-going material testing program by testing larger specimens containing hydrogen flakes, with the following 2 objectives:
 - Objective 2: An experimental confirmation of the suitability and conservatism of the 3D finite elements analysis.
 - LICENSEE ACTION: Bending test on samples with hydrogen flakes
 - The objective is to show that the experimental load of first brittle initiation of a flake in a large specimens with flakes is larger than the initiation load by 3D finite element model



2013-03-13 Doel 3 & Tihange 2 RPV Issue

7. Structural integrity assessment "Load test"

FANC REQUIREMENTS (Prerequisite to restart of units)

- Some uncertainty in structural integrity assessment needs to be dealt with additional experimental validation
- The licensee shall perform a load test of both reactor pressure vessels, accompanied with acoustic emission testing (during) and ultrasonic inspections (before & after).
- The acceptance criterion will be that no crack initiation and no crack propagation are recorded under the pressure loading.

2013-03-13 Doel 3 & Tihange 2 RPV Issue



8. FANC Conclusions – Current situation

- Some open issues remaining
 - Do not represent conditions requiring a definitive shutdown of Doel 3 and Tihange 2
 - Requirements formulated which need to be fulfilled by licensee before restart
- Licensee action plan to be elaborated and submitted to regulatory body for approval (DONE: 06/02/2013)
- · Licensee actions ongoing
- Once licensee has implemented action plan, FANC Bel V – AIB-Vinçotte will evaluate results (end of march?)
- FANC will motivate decision on restart of Doel 3 & Tihange 2 in subsequent final evaluation report

2013-03-13 Doel 3 & Tihange 2 RPV Issu



Implications for other RPVs in the world **Need for inspections - investigations?**

- Belgian reactors ✓ Other Belgian Reactors (different manufacturers)
 - Tihange 1 (LTO): april 2013 Tihange 3: end of 2013
- Foreign (RDM) reactors

 - ✓ Muhleberg (Switserland): no indications found ✓ Ringhals 2 (Sweden): no indications found ✓ Borssele (Netherlands): inspections planned 2013





More information FANC-website

Questions?

